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Inerting Aircraft Fuel Systems Using Exhaust Gases

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Introduction

Our purpose in this proposal was to determine the feasibility of using carbon dioxide, possibly obtained from aircraft exhaust gases as a substance to inert the fuel contained in fuel tanks aboard aircraft. To do this, we decided to look at the effects carbon dioxide has upon commercial Jet-A aircraft fuel. In particular, we looked at the solubility of CO₂ in Jet-A fuel, the pumpability of CO₂-saturated Jet-A fuel, the flashpoint of Jet-A fuel under various mixtures of air and CO₂, the static outgassing of CO₂-saturated Jet-A fuel and the dynamic outgassing of Jet-A fuel during pumping of Jet-A fuel.

Solubility of CO₂ in Jet-A fuel

The solubility of CO₂ in Jet-A aircraft fuel was determined by dissolving carbon dioxide into a known weight of Jet-A fuel at a fixed temperature of 25 °C. After exposing the fuel sample to carbon dioxide and stirring the sample for a period of 1 hour, the amount of dissolved carbon dioxide was determined gravimetrically using a Cahn 1030 microbalance. After several repeat analysis the average value for CO₂ solubility in Jet-A fuel at 25 C was found to be 750ppM. This corresponds to a solubility about twice that for Nitrogen.

This solubility is significantly higher than that of nitrogen and thus further testing of the ability of fuel saturated with carbon dioxide to function in an acceptable manner was deemed necessary.

Pumpability of CO₂ saturated Jet-A aircraft fuel.

Next, we decided to look at the ability of Jet-A fuel that has been saturated with CO₂ at 1.5 atm CO₂ pressure to be pumped using a pumping system similar to that used in a Boeing 747 aircraft. To do this we chose to use a variable speed turbine pump identical in size and similar in design to that used as the main fuel routing pump in the Boeing aircraft. This pump was driven by a 3hp electric motor with a motor controller capable of controlling motor rotation to the nearest Hz. For comparison experiments, we chose to use Jet-A saturated with 1.5 atm of air. The fuel resevoir consisted of a 55 gal drum filled with 35 gal of Jet-A fuel. The drum was externally pressurized with 1.5 atm of either CO₂ or air. The gas was circulated through the fuel for a period of 2h prior to each experiment to ensure that gas saturation had occurred. A plot of pump speed versus fuel flow is given in figure 1.

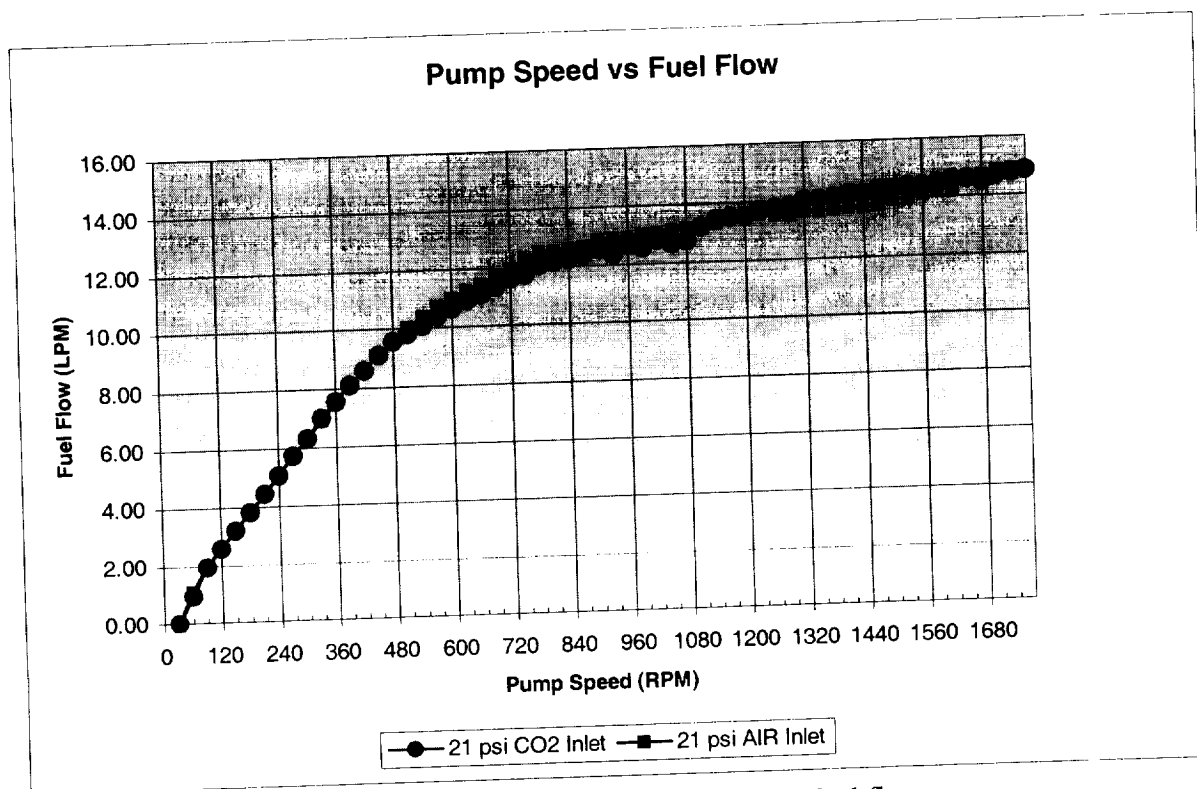


figure 1: plot of pump speed vs fuel flow

As can be seen, from figure 1, there is no effect of CO₂ saturation on the pumping velocity compared to air. The flowrate is neither slowed or altered in any way. Thus it should be possible to store fuel under CO₂ with no deleterious effects on the pumpability of the material.

Ignition tests of fuel stored under CO₂

Next we turned our attention to the effect of CO₂ on the ignition temperature on the fuel. We wanted to determine which had the larger effect on ignition temperature elevation, carbon dioxide or nitrogen. In these tests a standard micro flash apparatus was used in determining the flash point of Jet-A fuel in the presence of various concentrations of either CO₂ or N₂ in air.

For each data point, 2 mL of Jet-A fuel was placed in a closed cup flash apparatus. The atmosphere in the cup was fixed using premixed air and inert gas fed directly into the cup. The cup was then heated and tested for ignition, at the first sign of ignition the temperature was recorded. Figure 2 shows a plot of ignition temperature versus inter gas concentration for both nitrogen and carbon dioxide as inerting gas.

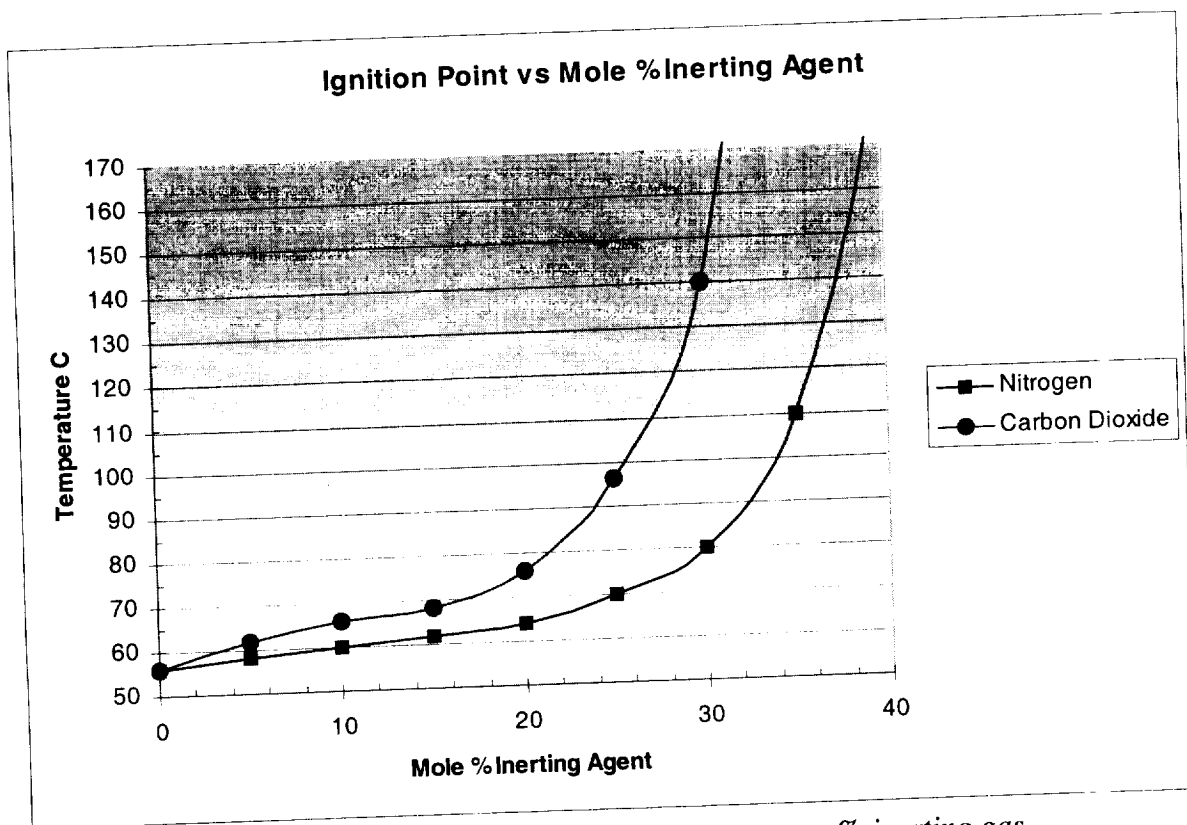


figure 2: plot of ignition temperature vs % inerting gas

Carbon dioxide has a larger effect on flash point elevation than nitrogen because of the difference in density between carbon dioxide and nitrogen. Carbon dioxide is 1.6 times denser than nitrogen and this increased density provides better blanketing of the fuel by CO_2 . In other words, it takes significantly more nitrogen to obtain the same flash inhibition with nitrogen than with carbon dioxide.

Two further tests of Jet-A / carbon dioxide fuel interactions were suggested by Dr. Clarence Chang, of the Aviation Safety Branch of NASA Glenn Research Center. The first was a static test for CO_2 evolution from Jet-A fuel saturated with carbon dioxide. The second test was a dynamic pumping test of Jet-A fuel saturated with CO_2 in which the hoses used to carry the pumped fuel were replaced with clear hoses to see if bubble formation was occurring within the pumped liquid.

Static gas evolution Experiments.

For the static test, a sample of Jet-A fuel was saturated with 2 atm of carbon dioxide for a period of 2 hours to ensure complete saturation. The carbon dioxide atmosphere was then removed and the sample opened to ordinary atmosphere and observed for a period of fifteen minutes. A photograph of the sample is given in figure 3. As can be seen in the photograph, no gas evolution has or did occur after opening the system to atmosphere.

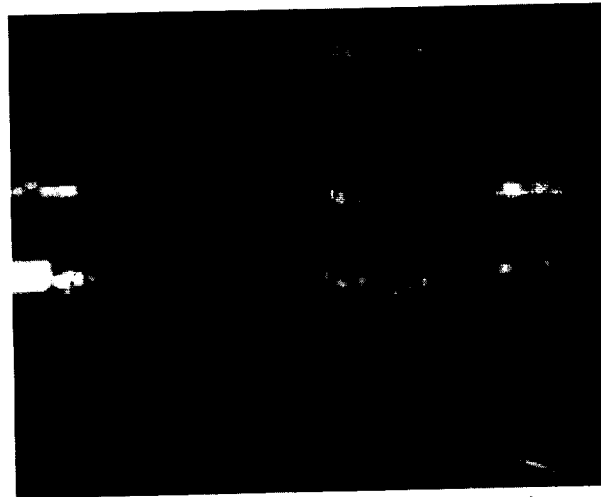


figure 3: Static test for CO₂ outgassing

Dynamic gas evolution Experiments.

We repeated the gas pumping experiments using clear 1.25 in. plexiglas tubing to carry the fuel so that the liquid could be observed during the pumping process. Both air and carbon dioxide saturated fuel was pumped for a period of 30 minutes each and the material was observed and photographed during this time. Figure 4 shows pumping of the air saturated liquid and Figure 5 shows pumping of the carbon dioxide saturated liquid.

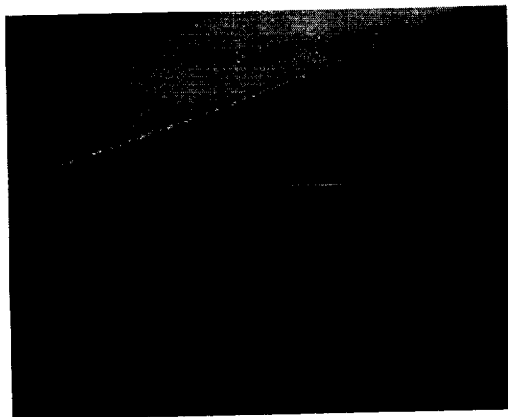


figure 4: CO₂ saturated fuel pumping



figure 5: Air saturated fuel pumping

No difference could be discerned between the two system.

Conclusions

Carbon dioxide appears to cause no deliterious effects on the ability of Jet-A to be pumped in a simulated fuel delivery system. Moreover, carbon dioxide appears to provide better flash inhibition than does nitrogen on Jet-A aircraft fuel.